Part 1: Adapted from Astropy Tutorial On Viewing and Manipulating FITS Images

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Learning Goals

1. Learn how to open FITS files and load the image data
2. Learn how to visualize the image data
3. Learn about basic image math: image stacking
4. Learn how to write image data to a FITS file

Keywords

matplotlib, FITS image, table

Summary

This tutorial demonstrates the use of `astropy.utils.data` to download a data file, then uses `astropy.io.fits` to open the file, and lastly uses `matplotlib` to view the image with different color scales and stretches and to make histograms. In this tutorial we've also included a demonstration of simple image stacking.

In [0]:
```
import numpy as np

# Set up matplotlib
import matplotlib.pyplot as plt
%matplotlib inline

from astropy.io import fits
```

The following cell is needed to download the example FITS files used here.

In [0]:
```
from astropy.utils.data import download_file
image_file = download_file('http://data.astropy.org/tutorials/FITS-image
s/HorseHead.fits', cache=True )
```

```
Downloading http://data.astropy.org/tutorials/FITS-images/HorseHead.fit
s [Done]
```

Opening FITS files and loading the image data

Let's open the FITS file to find out what it contains.

In [0]:
```
hdu_list = fits.open(image_file)
hdu_list.info()
```

```
Filename: /root/.astropy/cache/download/py3/2c9202ae878ecfcb60878ceb638
37f5f
No.    Name      Ver    Type      Cards   Dimensions   Format
  0  PRIMARY       1 PrimaryHDU     161   (891, 893)   int16
  1  er.mask       1 TableHDU        25   1600R x 4C   [F6.2, F6.2, F6.
2, F6.2]
```

Generally, the image information is located in the `PRIMARY` block. The blocks are numbered and can be accessed by indexing `hdu_list`.

In [0]:
```
image_data = hdu_list[0].data
```

Our data is now stored as a 2-D numpy array. But how do we know the dimensions of the image? We can simply look at the `shape` of the array.

In [0]:
```
print(type(image_data))
print(image_data.shape)
```

```
<class 'numpy.ndarray'>
(893, 891)
```

Great! At this point, we can close the FITS file because we've stored everything we wanted to a variable.

In [0]:
```
hdu_list.close()
```

SHORTCUT

If you don't need to examine the FITS header, you can call `fits.getdata` to bypass the previous steps.

In [0]:
```
image_data = fits.getdata(image_file)
print(type(image_data))
print(image_data.shape)
```

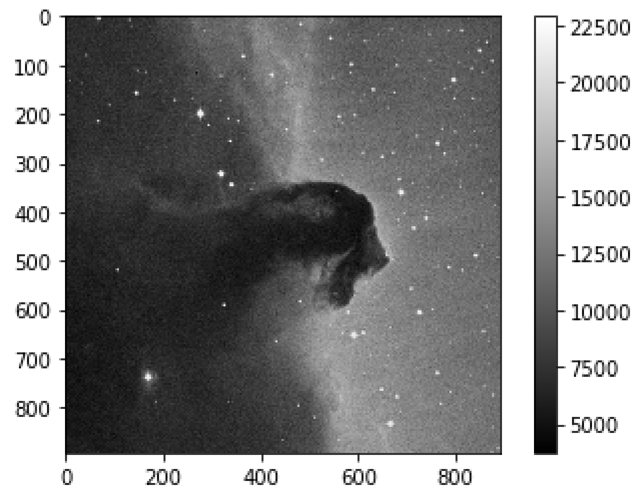
```
<class 'numpy.ndarray'>
(893, 891)
```

Viewing the image data and getting basic statistics

In [0]:
```
plt.imshow(image_data, cmap='gray')
plt.colorbar()

# To see more color maps
# http://wiki.scipy.org/Cookbook/Matplotlib/Show_colormaps
```

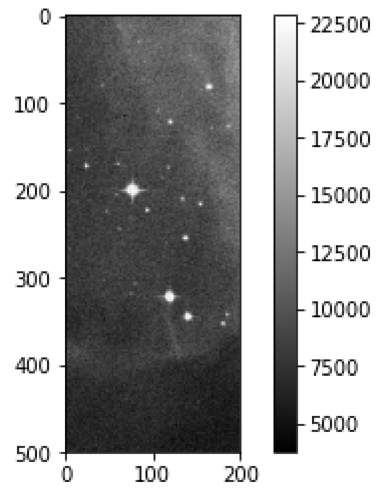
Out[0]:
```
<matplotlib.colorbar.Colorbar at 0x7fcae44d3208>
```



We can select parts of the array to plot, using indexing.

In [0]:
```
plt.imshow(image_data[0:500,200:400],cmap='gray')
plt.colorbar()
```

Out[0]:
```
<matplotlib.colorbar.Colorbar at 0x7fcae443add8>
```



Let's get some basic statistics about our image:

In [0]:
```
print('Min:', np.min(image_data))
print('Max:', np.max(image_data))
print('Mean:', np.mean(image_data))
print('Stdev:', np.std(image_data))
```

```
Min: 3759
Max: 22918
Mean: 9831.481676287574
Stdev: 3032.3927542049046
```

We can use similar numpy functions to find the location of the minimum and maximum of the data.

In [0]:
```
min_coord = print(np.where(image_data == np.amin(image_data)))
```

```
(array([116]), array([268]))
```

Verify that the data at that location does have the minimum value, found above

In [0]:
```
image_data[116,268]
```

Out[0]:
```
3759
```

In [0]:
```
max_coord = print(np.where(image_data == np.amax(image_data)))
print(max_coord)
```

```
(array([71]), array([850]))
None
```

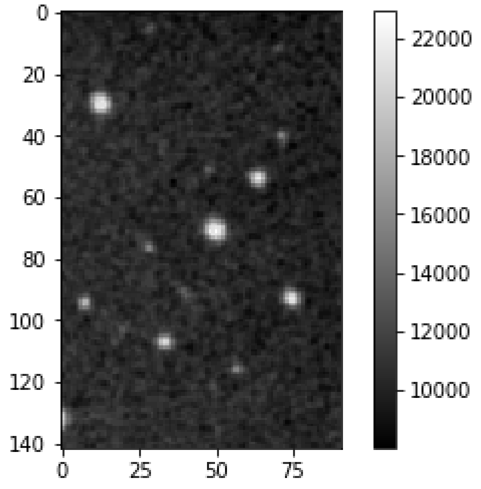
In [0]:
```
image_data[71,850]
```

Out[0]:
```
22918
```

In [0]:

In [0]:
```
plt.imshow(image_data[0:71*2,800:900],cmap='gray')
plt.colorbar()
```

Out[0]:
```
<matplotlib.colorbar.Colorbar at 0x7fcae01acd30>
```

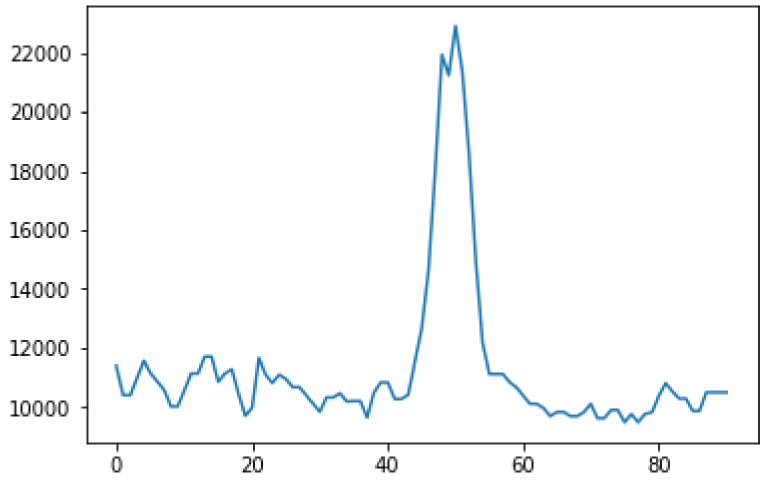


In [0]:
```
```

We can also plot a 1D "slice" of the image

In [0]:
```
plt.plot(image_data[71,800:900])
```

Out[0]:
```
[<matplotlib.lines.Line2D at 0x7fcae0123198>]
```



In [0]:
```
star_slice = image_data[71,800:900]
no_signal = star_slice[0:40]
print(np.std(no_signal))
```

```
545.057748660635
```

```
In [49]: baseline = 10000
         peak = 22000
         noise = 500
         signal = peak - baseline
         sn_ratio = signal/noise
         print('Estimated signal to noise ratio is: ', sn_ratio)

         Estimated signal to noise ratio is:  24.0
```

Plotting a histogram

To make a histogram with `matplotlib.pyplot.hist()`, we'll need to cast the data from a 2-D array to something one dimensional.

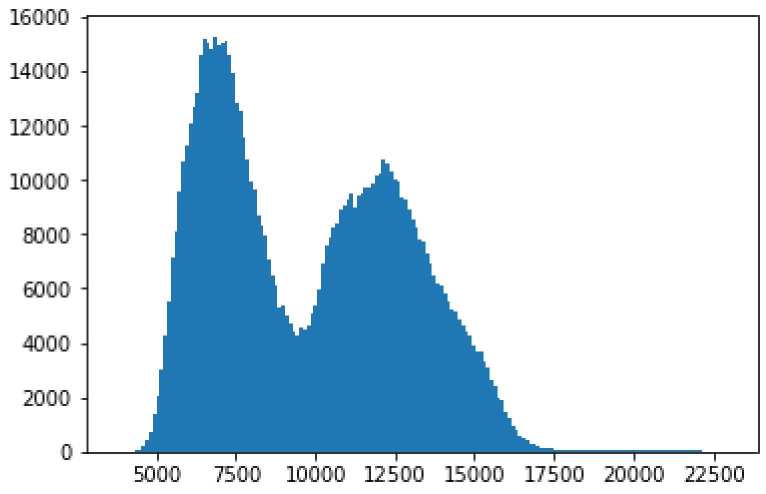
In this case, let's use the `ndarray.flatten()` to return a 1-D numpy array.

```
In [0]: print(type(image_data.flatten()))

        <class 'numpy.ndarray'>
```

```
In [0]:
```

```
In [0]: histogram = plt.hist(image_data.flatten(), bins='auto')
```


16000
14000
12000
10000
8000
6000
4000
2000
0
5000
7500
10000
12500
15000
17500
20000
22500